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ABSTRACT

This paper examines the cost-benefit implications of alternative pricing and capacity investment decisions for automated scientific and technical information retrieval systems. Two typical systems are examined and numerical examples presented. In the first system, search requests are entered on-site. The show how setting price to maximize net social benefit precludes total cost recovery and implies subsidization. In the second hypothetical system, search requests are entered from remote access terminals. Allowance is made for random arrival rates, and distinction is made between system charges to users and other user incurred costs. With these refinements, the numerical examples show how, for certain ranges of output, total cost recovery is consistent with the maximization of net social benefit. The paper then examines the "public good" attributes of scientific and technical information retrieval systems and concludes that such systems can be viewed as "semi-public goods," since the information stored has the characteristics of a public good while access to this information has the characteristic of a private good. Based on the public good considerations and the numerical examples, the paper concludes that subsidization for the fixed costs is warranted to the extent that all reasonable alternatives which maximize net social benefit preclude total cost recovery. (Author)

Cost Recovery in Pricing and Capacity Decisions for Automated Information Systems

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COST RECOVERY IN PRICING AND CAPACITY DECISIONS FOR AUTOMATED INFORMATION SYSTEMS

by

JAMES A. DEI ROSSI*

ABSTRACT

This paper examines the cost-benefit implications of alternative pricing and capacity investment decisions for automated scientific and technical information retrieval systems. Two typical systems are examined and numerical examples presented. In the first system, search requests are entered on-site. The numerical examples show how setting price to maximize net social benefit precludes total cost recovery and implies subsidization. In the second hypothetical system, search requests are entered from remote access terminals. Allowance is made for random arrival rates, and distinction is made between system charges to users and other user incurred costs. With these refinements, the numerical examples show how, for certain ranges of output, total cost recovery is consistent with the maximization of net social benefit. The paper then examines the "public good" attributes of scientific and technical information retrieval systems and concludes that such systems can be viewed as "semi-public goods," since the information stored has the characteristics of a public good while access to this information has the characteristic of a private good. Based on the public good considerations and the numerical examples, the paper concludes that subsidization for the fixed costs is warranted to the extent that all reasonable alternatives which maximize net social benefit preclude total cost recovery.

Key Words: Automated information retrieval; cost-benefit; public good; scientific and technical information; semi-public good; subsidization; total cost recovery; user charges.

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COST RECOVERY IN PRICING AND CAPACITY DECISIONS
FOR AUTOMATED INFORMATION SYSTEMS

I. INTRODUCTION AND OVERVIEW

Should fees be charged for the use of scientific and technical information products and services? And, if so, should such fees be set at a level that will result in total cost recovery? Since the alternative to total cost recovery is subsidization, the issue of total cost recovery is critical to the future growth and development of automated scientific and technical information retrieval systems that are fully or partially financed with public funds. However, the answers to the questions posed have been clouded by both the importance of scientific and technical information to the public as a whole, and by the dominant role of publicly sponsored activities in the areas of science and technology. Both of these factors have reinforced the "public good" appearance of scientific and technical information in a nation where the importance of free access to information has been a long-standing tradition.

When scientific and technical information is viewed as a public good, little attention is given to the role of price. Free library service and the 10¢ government publication are examples of the public good approach which has also been applied to the use of scientific and technical information However, as the cost of providing access to scientific and technical

information has increased, attitudes have shifted to considering the treatment of such information as a private good, and numerous opinions have been expressed that price should be used to insure total cost recovery.

In contrast to these opposite poles of thought, the conclusion of this paper is that scientific and technical information products and services are in the domain of what has been referred to as the "semi-public" good. Unlike public goods, it is felt that the provision of scientific and technical information products and services should utilize price and the market place as a means for determining the allocation of resources. However, unlike the provision of private goods, total cost recovery is not viewed as the appropriate criterion for establishing prices.

Public goods, which are "enjoyed but not consumed," are largely unaffected by the number of persons benefiting from them. National defense and law and order are familiar examples of such public goods. Private goods, however, are consumed, in the sense that each person's enjoyment affects the availability of these goods to others, and the cost of producing these goods is roughly proportional to the number of persons benefiting. The ideas and concepts constituting the body of scientific and technical knowledge have the property of a public good, since they are not consumed when enjoyed. However, access to these ideas and concepts, as provided for through information services and products has the attribute of a private good in that the numbers of persons utilizing them affects both cost and availability.

Because of the semi-public-good nature of scientific and technical information products and services, it can be concluded that net social benefit rather than total cost recovery should be taken as the criterion for establishing appropriate prices.* Accepting this conclusion, several questions immediately follow: How can net social benefit be measured? What are the pricing rules for maximizing net social benefit? Does pricing according to such rules preclude total cost recovery and imply subsidization for automated scientific and technical information retrieval systems?

The body of this paper begins by examining the role of market prices in measuring social value, using the conventional economic concept of "consumer surplus." Based on this concept, market responses as reflected in the demand for an information product or service can be used to derive a measure of the total social value of that product or service. The difference between this total social value and the cost of producing that same product or service is taken as the net social benefit derived from its production and consumption.

Using standard mathematical techniques, Appendix A shows that the maximization of net social benefit occurs when price is set equal to marginal cost.** In contrast, total cost recovery implies setting price equal to average cost. Thus, the effect of using the maximization of net social benefit to establish price for the services and products of automated scientific and

*The focus of this paper is on publicly operated or publicly funded access to scientific and technical information. However, the logic can be equally applied to such access provided by information centers within private organizations. In this latter case, it would be argued that the information service department should set its prices using the benefit of the organization as a whole to establis prices, rather than cost recovery for that department.

**Marginal cost is the amount by which total cost increases for each additional unit of output and, thus, can be thought of as the cost of producing the last unit of output.

technical information retrieval systems rests on the relationship between marginal cost and average cost in the operation of such systems. If marginal cost is greater than or equal to average cost, setting price equal to marginal cost would be consistent with the goal of total cost recovery. However, if marginal cost is less than average cost, total cost will not be recovered, and some form of subsidization is implied. The question then becomes: Is the value of total benefit greater than the total cost of production plus the implied subsidy; i.e., is there a positive net benefit? Unless the answer to this question is affirmative, there is no economic justification for subsidization.

The precise relationship between marginal cost and average cost will vary among systems, based on the unique organizational and technological characteristics of each. However, typical relationships between these two types of cost for automated scientific and technical information retrieval systems can be established by a careful analysis of operational characteristics and cost factors based on actual experience. Such relationships are developed in this paper for two specific, hypothetical systems to illustrate how the techniques of operations research and economic analysis can be used to evaluate prices for actual systems, and to provide numerical examples of the application of cost-benefit analysis to both pricing and capacity investment decisions.

In the first hypothetical system, requests for searches are entered on-site. In the second, requests for searches are entered from remote access terminals. Thus, the two systems chosen are representative of two major classes of automated information retrieval systems. Interestingly, the cost relationships for each type of system differ dramatically. For the on-site entry system, average cost is always greater than marginal cost, implying the need for some form of subsidy if a socially optimum level of output is to be sustained. For

the remote entry system, distinction between system charges to the users and other user incurred cost, and allowance for the congestion implications of the random nature of remote-entry arrival rates, show that marginal cost can be greater than average cost for certain ranges of output.

The ranges of output over which marginal cost is greater than average cost depend on the rate of search requests relative to the total output capacity of a system. Therefore, before presenting the cost data and examples, the paper examines the concept of capacity and the relationships among capacity, rate of search request arrivals, and search time. Using search time required per search as a measure of performance, it is shown how the specification of minimum performance (search time) criteria can be used to identify the "effective capacity" of an automated information retrieval system; i.e., the maximum search request rate that can be processed without violating the specified performance requirements. It is at this point that the concept of congestion and its impact on search time are introduced. In the later sections, effects of increased search time on marginal cost are examined.

Using the cost data, the performance criteria, and various postulated levels of demand, numerical examples are developed to examine the cost-benefit implications of alternative pricing and capacity investment decisions. The general implications of the specific findings are then discussed. In all, there are four examples presented, two for each system. In the first two examples, the impacts of pricing policy on net social benefit and total cost recovery are examined, for a given and fixed output capacity. In the other two examples, the net social benefit and total cost recovery implications

of pricing alternatives together with char :s in capacity are examined. A summary tabulation of these examples, indicating the order in which they are presented is as follows:

	On Site	Remote Access
Fixed Capacity	Case 1	Case 2
Variable Capacity	Case 3	Case 4

The results for the on-site entry examples show how maximizing net social benefit will generally be inconsistent with total cost recovery for this type of system. Setting price equal to marginal cost will result in increased output, lower user cost, and increased net social benefit than would occur by setting price equal to average cost in order to recover total cost. However, because marginal cost is likely to be constant for this type of system, setting price equal to marginal cost also will entail a loss to the extent of the total fixed cost of the system. Thus, a socially optimum price with on-site entry implies the recovery only of costs which vary with the level of output and the subsidization of fixed costs. This roughly is equivalent to subsiziding the "public good" component of the system and recovering the costs of the "private-good" component.

The results for the remote-entry examples show that total cost recovery and the maximization of net social benefit are not always inconsistent. To demonstrate this it is necessary to distinguish between system charges to the users and other user incurred costs; i.e., to recognize that not all user costs are paid to the producer. With this distinction and appropriate allowance for the increases in search time that occur as utilization rates increase, it is shown how, under certain circumstances, it is possible to set price so as to maximize net social benefit and still recover total cost.

The major implication of these findings is, therefore, that the decision to subsidize rather than to set price so as to recover full cost should be based on careful analysis and not simply on the public-good-concept. Only if it can be demonstrated that total cost recovery is not feasible for all reasonable pricing and capacity investment alternatives, should subsidization occur. And, second, if subsidization is given, it should not exceed the value of the fixed cost or public-good component of the product or service.

II. MEASURING SOCIAL BENEFIT

From the viewpoint of promoting an economically efficient use of resources, price must be understood as a mechanism for allocating scarce resources. The distinction between price as an allocating mechanism and price as a device for recovering cost is an important one. Market prices, when understood as mechanisms for allocating scarce resources, can also be used to develop measures of social benefit. A brief review of the role of markets and prices in a market economy can be used to illustrate these ideas.

A. Direct Social Benefit

In deciding on specific purchases, individuals are continually weighing alternatives and determining how to spend or save their limited resources. Similarly, private firms select among alternatives in making their investment decisions. When markets are functioning properly, prices are bid up to th point where the available supply is allocated to the consumers who are willing to pay the highest price. Similarly, producers who are willing to pay the highest price for a resource are those whose product is most highly valued by members of society; i.e., the prices the producer is willing to pay for input resources are largely determined by the prices consumers are

willing to pay for the product or output of that producer. In this way, the prices consumers and producers pay reflect the values and priorities of society.

Thus, under appropriate conditions, the market approach provides a means for both efficient output distribution and efficient productive resource allocation:

> ". . . the conditions for pricing to work are fairly simple: users must be unable to obtain any scarce resource at a zero price; social and private direct benefits must be identical, so that neither benefits nor costs are incurred except by the buyer and seller; and prices must be free to vary without regard to the cost of production. (These are rigorous requirements; in fact, pricing will usually work if these requirements are loosely satisfied.)" [13]

When these conditions are met, the value of a good or service to consumers or buyers can be considered the value of that product to society. Therefore, the total benefit (value) to society derived from the consumption of a good or service when the conditions outlined above are met is the sum of the benefits (values) to each purchaser.

The demand curve, which shows the number of units purchasers are willing to purchase at a given price provides a means for calculating this sum of individual benefits. Figure 1 shows such a demand curve, labeled DD'. By the reasoning outlined above, the total social benefit (TB) derived from the consumption of Q units is given by the area under the demand curve from zero to Q; i.e., the area DBQO.

For a given price, P, a quantity, Q, will be demanded. The total revenue (TR) from providing Q units at price, P, is given by the area under the

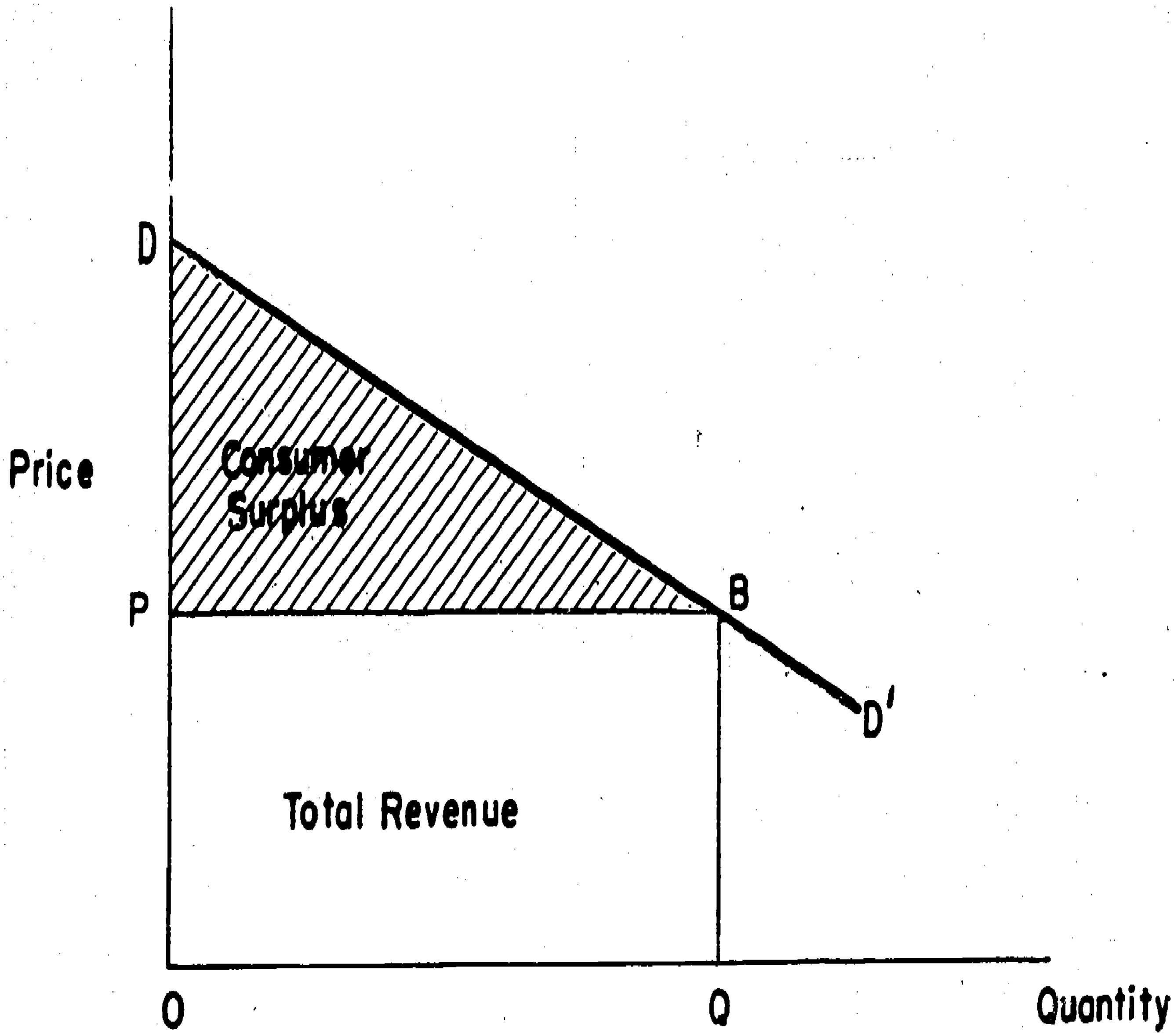

Figure 1. Total Revenue and Consumer Surplus

rectangle PBQO. The remaining area, DBP is "consumer surplus." Consumer surplus (CS) is the difference between the price that consumers pay for a good or service and the amount they would be willing to pay rather than do without. Thus, TB = TR + CS. By definition, the corresponding net social benefit (NB) is the total social benefit less the total cost (TC) of producing the Q units; i.e., NB = TB - TC.*

B. Indirect Social Benefit

Although direct social benefit as defined above is the measure that will be used in the following examples, it is well to recognize that, in the actual evaluation of systems, indirect benefits and externalities should also be considered. The recent report of the Panel of Economics of the Science Information Council [5, p. 40-51] presents a useful discussion on the issue of quantifying total indirect and direct benefit.

The direct benefit calculation based on market response and consumer surplus can be viewed as an approximate lower bound on net benefit, as the Report of the Task Group on the Economics of Primary Publications points out [9, p. 8]. Following this logic as presented for journals, the relationship between the direct and total social value of automated scientific and technical information system services can be expressed as:

$$\text{Total Social value} = \text{Value to current users} + \text{Value to others, including future generations}$$

*In cases where cost or benefits are external to the market and not reflected in the cost of production or the market price, social cost (benefit) is not equal to private cost (benefit). In these cases there is said to be a market failure due to externalities. With external benefits, total benefit will be understated. With external costs total benefits will be overstated. The allocation by market price is still viewed, in principle, as efficient when external cost is involved if the net benefit is high enough to compensate for the external costs.

And, the first term also consists of two parts: Current users receive information both directly via their own use of the systems, and indirectly, via contacts with others who have used them. Thus,

$$\text{Value to current users} = \text{Current direct value} + \text{Current indirect value}$$

The measure of net benefit described reflects only the first term of this second equation, current direct benefit.

III. MAXIMIZING NET BENEFIT

Using the measure of direct social benefit described above, methodology for evaluating alternative pricing and capacity investment decisions, in terms of their impact on net benefit, can be applied. The derivation of the net-benefit-maximizing price is described in Appendix A for both the general case and the case where there is a constraint on output capacity. The appendix shows that for the general case, net social benefit is maximized when

$$P = MC, \qquad (1)$$

where

P = price

and

MC = marginal cost,

the cost of producing the last unit of output. In contrast, when the objective is to maximize producer benefit (profit) rather than net social benefit, the maximizing condition is MC = MR, where MR (marginal revenue) is the increase in total revenue from the sale of the last unit of output.

When the demand curve has a negative slope, some degree of monopoly or market power exists. This occurs when the size of the market is small relative to the producer and there is some distinctness or uniqueness in his product.

With a negative slope on the demand curve, the profit maximizing objective will lead to higher prices and lower levels of output. This is shown in Figure 2 where MR intersects MC at $Q1 < Q$ and the price required to hold demand at that level is $P1 > P$.

If an output capacity constraint is operative, as would occur when the demand curve intersected the vertical section of the MC curve at capacity output, Q^*, as shown in Figure 2 by the point A, the net benefit maximizing price would be:

$$P = MC + \lambda. \tag{2}$$

where λ is the vertical distance from the horizontal section of the MC curve to the point of intersection. It is the amount over the value of MC on the horizontal section which must be added to price in order to restrict demand to a level consistent with capacity.

IV. DEMAND AND CAPACITY

In this and the following sections hypothetical data are introduced to illustrate the application of cost-benefit analysis to pricing and capacity investment decisions, using the maximization of net social benefit as the criterion of evaluation. First, the demand function used in the examples presented is described. Second, a simple queuing model is presented as a basis for defining capacity. Next, system costs are defined and several pricing and capacity investment alternatives are examined and evaluated in terms of their impacts on net social benefit and cost recovery.

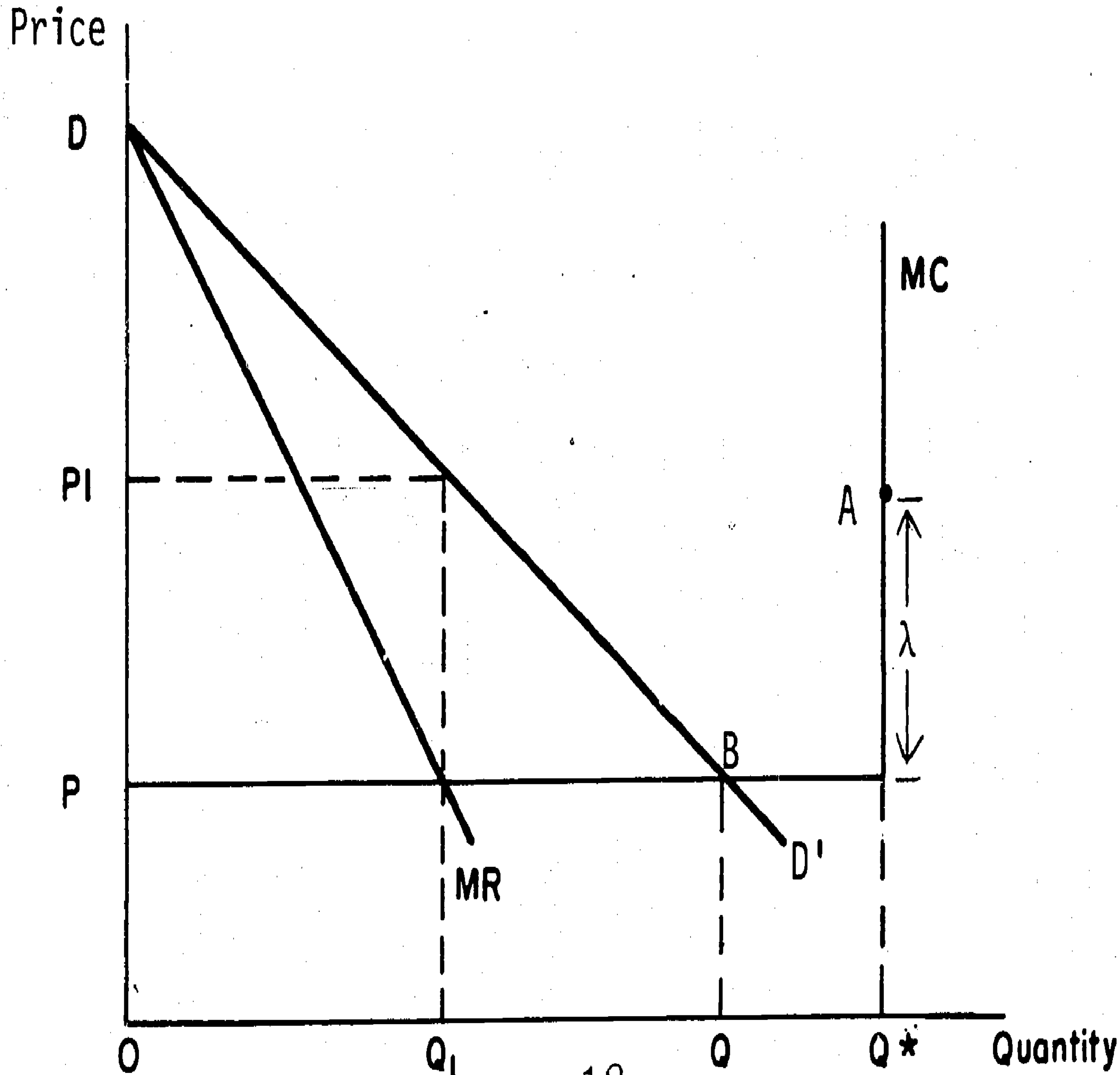

Figure 2. Optimal Short-Run Pricing

A. The Demand Function

There are of course many factors which affect the demand for any good or service, including information services. The major ones which would be part of a comprehensive demand analysis include:

1. The price and quality of the good or service.
2. The prices and quality of competing and complementary goods and services.
3. The number of buyers.
4. Buyer preference and income.

For relatively short time periods, buyer characteristics, including number, preferences, and income, can be taken as given and assumed to remain essentially unchanged. Similarly, the assumption that the prices and characteristics of competing and complementary goods and services remain unchanged is a reasonably accurate assumption for competitive markets for short time periods.

Quality of service has many dimensions. Characteristics such as relevancy, recall and precision are important [3, 18]. To keep the illustration manageable, only coverage will be explicitly treated in the demand analysis, and it will be treated through a surrogate variable: data base size. With these ground rules, demand, Q, can be expressed as a general function of price, P (cost to the user), and data base size, N;

$$Q = f(P,N) \qquad (3)$$

The existence of a relationship between price and demand is, of course, well documented. Evidence of the impact of "data base" size can be found in [2, p. 27, 29; 6, p. 645].

For purposes of examining the benefit implications of alternative price and capacity decisions, the "price elasticity of demand" is an important demand function characteristic. Price elasticity, σ, shows, the proportional change in Q for a proportional change in P:

$$\sigma = \frac{(\partial Q/Q)}{(\partial P/P)} \qquad (4)$$

If the absolute value of σ is greater than one, demand is said to be elastic. If it is less than one, demand is said to be inelastic. Inelastic demand curves have steeper slopes than elastic demand curves, and the implications of this difference are many. As an example, the difference between marginal revenue and average revenue is greater the less elastic demand is. Thus, average cost pricing will lead to a higher price and lower level of output relative to marginal cost pricing the more inelastic the demand curves are (see Figure 2).

Because of its reasonableness from a conceptual point of view and its elasticity properties, the following functional form for the demand function will be used in the examples which follow:

$$Q = Ae^{-\alpha P}\ e^{\beta N} \qquad (5)$$

This form has the property that elasticity is proportional to the values of the variables. Thus price elasticity for this form is given by $\sigma = -\alpha P$.

Similar calculations can be made for N. However, since the primary interest is in the effect of price changes on demand, changes in N will be viewed as quality related changes which shift the curve relating P and Q. The value of β for equation 5 will be chosen so as to make the value of $\beta N = .4$ [6, p. 645] for an assumed data base size of 350,000 documents.

To calculate total benefit for different values of Q, the integral of the inverse of this demand function is used:

$$TB = \int_0^q P(Q)dQ \tag{6}$$

For the first illustration, the demand curve will be chosen so as to intercept the average cost curve at Q=20,000. Such a curve with α chosen so as to make $\alpha P = -1.25$ at 20,000 is shown in Figure 6. Choosing the point of intersection and specifying the elasticities determines the value of A as well as the values of α and β, so that all the values needed to calculate total benefit for any specified quantity, q, are known.

B. Performance and Capacity

Although a uniform level of demand will be assumed over each 8 hour day, arrivals of requests will still be somewhat random, introducing an element of irregularity. Similarly, the amount of time required to service each request will fluctuate from search to search. With these elements of randomness, the performance of an automated information retrieval system is subject to random flaws and congestion, even under the assumption of uniform loading. When congestion occurs, queues develop, waiting time increases and performance degrades.

The concept of intensity of utilization or rate of utilization affords the simplest measure of congestion. It is defined as:

$$\rho = \frac{\lambda}{\mu} = \frac{\text{mean requests per unit of time}}{\text{mean service per unit of time}}, \quad 0 \leq \rho \leq 1 \tag{7}$$

Thus, λ is the mean arrival rate; μ is the mean service rate, and $1/\mu$ is the mean service time, S.

To illustrate the impacts of congestion on performance, a simple queuing model is used. The automated information system in the example will be viewed as a "single-server, no-loss" system, in which arrival rates are described by a Poisson distribution and service times follow a negative exponential distribution (see 11 and 21 for a discussion of these concepts).

With these assumptions, the mean waiting time, W, is [26, p. 318-319]:

$$W = \frac{\rho S}{(1-\rho)} \tag{8}$$

From this expression, it can be seen how waiting time increases as the intensity of utilization, ρ, increases and approaches one.

Service time for an automated information retrieval system has three components.

1. <u>Input time</u>: This is the time required to input the keywords of the search into the computer.
2. <u>Search time</u>: This time depends on the complexity of the request, the efficiency of the indexing system and the power of the system.
3. <u>Output time</u>: The time required to print out the search results.

Search times can be quite low. Assuming each request has 50 terms, with a data base and system similar to those described in [22], the average search time becomes $(0.0003334 \times 350 =)$ 0.1166 minutes. With front-end processers and off-line printing, the total service time could also be quite low. For our example a total input/output time of 2 minutes will be assumed initially, which means that S = 2.1166 minutes and $\mu = .4725$.

Assuming an 8 hour day, a 5 day week and 52 weeks per year gives 124,800 minutes per year of operation. The mean-arrival rate per minute, λ, can be expressed as 124,800 minutes per year divided into the number of requests per year. Thus, given S, the values of ρ and W can be calculated as a function of the annual number of requests by inserting S, 1/S, and λ into equations 7 and 8.

The expected waiting time is one major element of a minimum-required-performance criterion for an automated information retrieval system. However, since W is a random variable, random fluctuations will occur for any given level of utilization. A fully operational performance criterion also requires the specification of a level of confidence that the maximum waiting time will not exceed a given value. These levels of confidence are referred to as "percentiles." The $(1-\alpha)$-percentile is the probability that, on the average, $(1-\alpha) \times 100$ percent of the requests will have a waiting time less than t, and can be expressed as [26, p. 318-319]:

$$W(t) = (1-\alpha) = 1-\rho e^{-(\mu-\lambda)t} \qquad (9)$$

For the examples, the maximum waiting time required is set at 10 minutes to prevent excessive waste of input resources. The expected waiting time, W, and W(10) for α = .01, .05, .10 are shown in Figure 3 on semi-logarithmic coordinates for various annual numbers of requests, Q, and corresponding intensities of utilization, ρ. These calculations show that W=10 when Q=48,700 and ρ=.83.

However, when at Q=48,700, W(10)=.64. This means that on the average about 36 percent of the requests will have a waiting time greater than 10 minutes (i.e., α = .36). To achieve a higher probability that W will not exceed 10 minutes requires that fewer searches be processed. For example

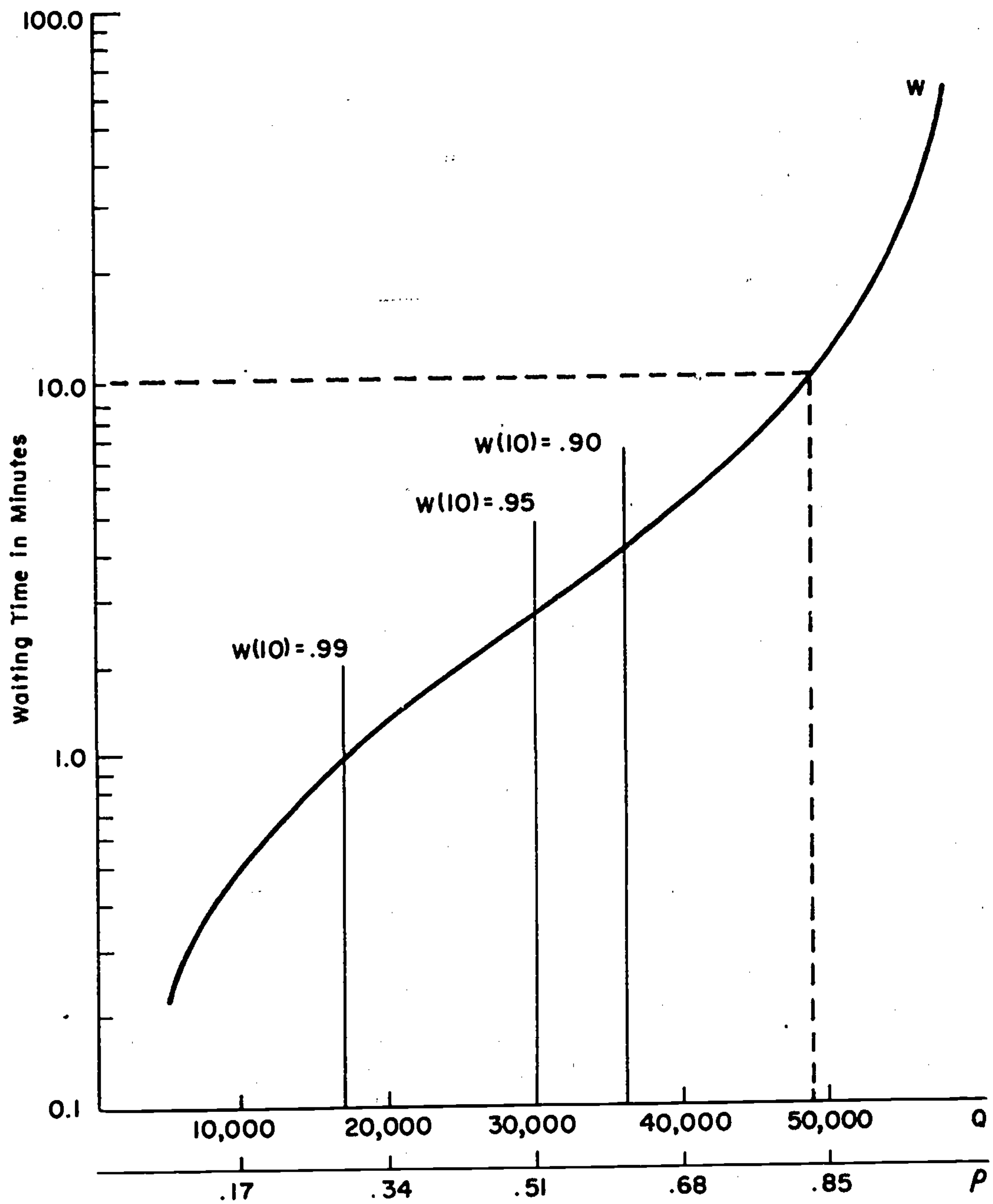

Figure 3 Waiting Time and Percentiles

to maintain $W(10) \geq .90$ would require that the number of requests, Q, be less than or equal to 36,000. Similarly, $W(10) \geq .95$ requires $Q \leq 30{,}000$ and $W(10) \geq .99$ requires $Q \leq 17{,}000$.

For the examples, the value of W(10) will be set at .95. By so doing the "effective capacity" of the system with S = 2.1166 is set at 30,000 search requests per year. This means that pricing alternatives for the capacity size will be required to maintain price sufficiently high to insure that the number of searches demanded will be 30,000 or less.

V. ON-SITE ENTRY, FIXED CAPACITY

To illustrate the application of cost-benefit methodology in the economic evaluation of alternative pricing decisions, hypothetical, but realistic, cost data will be combined with the capacity criteria and demand function previously described. In this section, a system with on-site entry, together with its costs will be presented. Then, the impact of alternative short-run (fixed capacity) pricing decisions on net social benefit will be examined. Following this, a remote entry system will be described and similar pricing alternatives examined. Finally, the costs of increasing capacity will be discussed, capacity-cost relationships postulated, and alternative pricing and capacity investment decisions for both systems examined.

A. System Cost

The literature on the costs of information retrieval systems is fairly extensive. Annual surveys can be found in a separate chapter of

each Annual Review of Information Science and Technology [4]. A particularly useful study of cost is contained in a recent book by Bryant and King [3, p. 36-87], which contains a model of the cost of retrospective information systems based on work performed for the American Psychological Association [14]. A modified version of this model will be used as the basis for the analysis of scientific information retrieval system cost.

Bryant and King point out that "the total cost of any given retrospective search system is composed of three types of costs:

1. Fixed costs (capacity) . . .
2. Variable costs dependent on the number of items input into the system, and
3. Variable costs dependent on the number of searches conducted." [3, p. 73]

Symbolically, this can be expressed as:

$$TC = F + bQ \qquad (10)$$

or

$$TC = f + aN + bQ, \qquad (11)$$

where TC = Total Cost per year
F = Annualized total fixed cost
f = Annualized fixed cost associated with capacity
a = Cost per item input
b = Cost per search
N = Number of items input per year
Q = Number of searches per year

Other assumptions of the Bryant-King model are: "on-line (on-site) system (inputting), including manual indexing for input, a thesarus to use for input as well as searching, user requests processed through an intermediary by telephone or in writing, and searches that, on the average, retrieve 80 per ce of the relevant items. Screening is performed on search output, and stracts of the identified documents are sent to the user." [3, p. 73-74]

With the cost model for the system as described, Bryant and King examine the questions of pricing for various cost allocation rules, assuming that four products and services are sold:

1. Restrospective Searches
2. Tape Sales
3. Current Awareness Services
4. Recurring Bibliographies

The major characteristics of the cost curves do not change under the various cost allocation assumptions used in the book. For the sake of ease of exposition, it will be assumed in the example that only retrospective searches are provided so that there are no additional costs and no allocation considerations to be examined.

1. <u>Capacity Cost</u>

For analyzing fixed cost, Bryant and King identify "subsystems" with fixed costs:

1. User/system interface
2. Input
3. Search
4. Screening
5. Presentations

The fixed cost associated with each subsystem includes staff, space rental and equipment costs. The total fixed capacity cost then is:

$$f = C_1 + C_2 + C_3 + C_4 + C_5, \qquad (12)$$

where each of the C_i are the fixed costs associated with each of the correspondingly numbered subsystems. For example, the following values are assumed:

C_1 = fixed cost of user/system interface are \$2,500, amortized over 5 years with a 6 percent capital recovery factor [10, p. 113] =	\$ 595
C_2 = fixed cost of input are \$25,000, amortized over 5 years with a 6 percent capital recovery factor =	\$ 5,925
C_3 = fixed search costs include: computer rental, space, staff and fixed computer storage space =	\$135,000
C_4 = annual fixed cost of screening =	\$ 35,000
C_5 = fixed cost of mailing set-up are \$1,000, amortized over 5 years with a 6 percent capital recovery factor =	\$ 235
f = total annual fixed capacity cost =	\$176,755

2. Input Cost

To estimate annual input cost, a constant data base size of 350,000 citations will be assumed. The time over which the references cited in this data base continue to have informational value is assumed to be 5 years, at which time they are removed from the data base file. Both of these assumptions are somewhat simplifying but reasonable based on current practice.

With these assumptions, 70,000 documents are added to the data base each year, each requiring indexing, abstracting and keyboarding into

computer readable form. Computer-related processing costs for file loading and removing of citations are relatively minor and assumed to be provided as part of C_3. The assumed annualized unit cost of inputting is:

C_6 = input cost per item for indexing, abstracting and keyboarding are \$0.575, amortized over 5 years with a 6 percent capital recovery factor = \$0.136

Since $C_6 = a$ in equation 11, total annual input cost (aN) is $0.136 \times 350{,}000 =$ \$47,600.

3. Search Cost

It is assumed that an average of 125 documents are retrieved per search and 25 documents are relevant and mailed. The unit search costs are:

C_7 = cost of user/system interface per search = \$ 15

C_8 = cost of screening per item retrieved per search = \$0.125

C_9 = cost of mailing per relevant item per search = \$ .10

Thus, variable cost per search is:

$$b = C_7 + 125 \times C_8 + 25 \times C_9 \qquad (13)$$
$$= \$33.13$$

4. Total Cost

Total cost for various numbers of searches based on the cost factors described are shown in Figure 4. The corresponding average total and marginal (average variable) cost curves are shown in Figure 5. Total cost

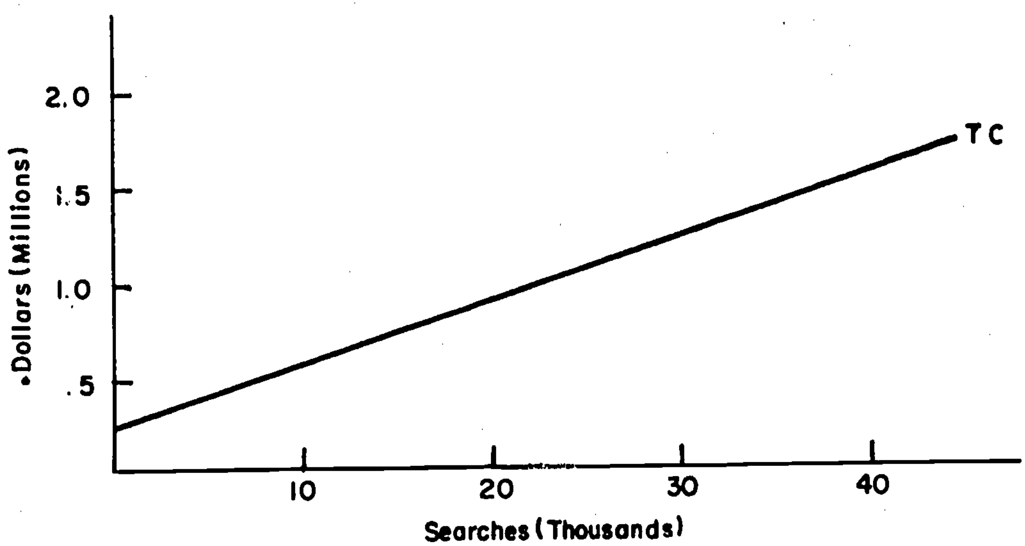

Figure 4. Total Cost

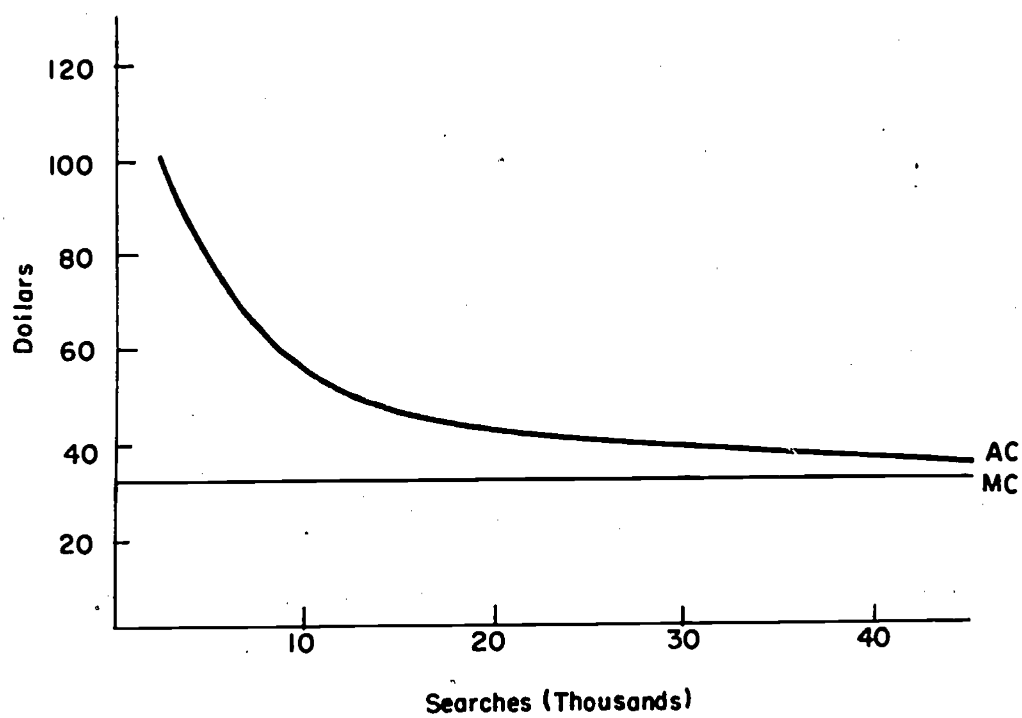

Figure 5. Average and Marginal Cost

is a linear function of the number of searches, since marginal cost is constant at \$33.13. Average total cost declines over the whole range of output and asymptotically approaches marginal cost, reflecting the allocation of the fixed portion of cost to larger quantities of output.

These curves illustrate how a conflict between the goals of total cost recovery and maximization of net social benefit can arise. When MC is equal to some constant, b, up to capacity, and $F > 0$, as shown in Figure 5, $AC = (F/Q + b)$ so that $MC < AC$ for all Q. When this occurs the net benefit maximizing solution of $P = MC$ is not consistent with total cost recovery since $TR = MC \times Q < TC = AC \times Q$. This situation exists for many automated information retrieval systems and is a factor in support of subsidization of publicly financed systems. This issue will be discussed further after a more detailed analysis of the outcomes of various pricing and capacity investment decisions.

B. Pricing Alternatives

For the on-site, fixed capacity example, the demand curve has been chosen to intersect the average cost curve at Q=20,000 and AC=\$45.35, as shown in Figure 6. Thus, if price is set equal to average cost (P=AC=\$45.35), demand will be 20,000 and total revenue (P x Q) will just equal total cost (AC x Q). At this point, total benefit is the area under the deman[illegible] calculated by integrating from Q equals 0 to 20,000 using equation 6; total cost is the area under the rectangle from the average cost curve at 20,000 to each of the axes; and consumer surplus is the difference between total benefit and total cost. These numbers are shown below under the column headed P = AC.

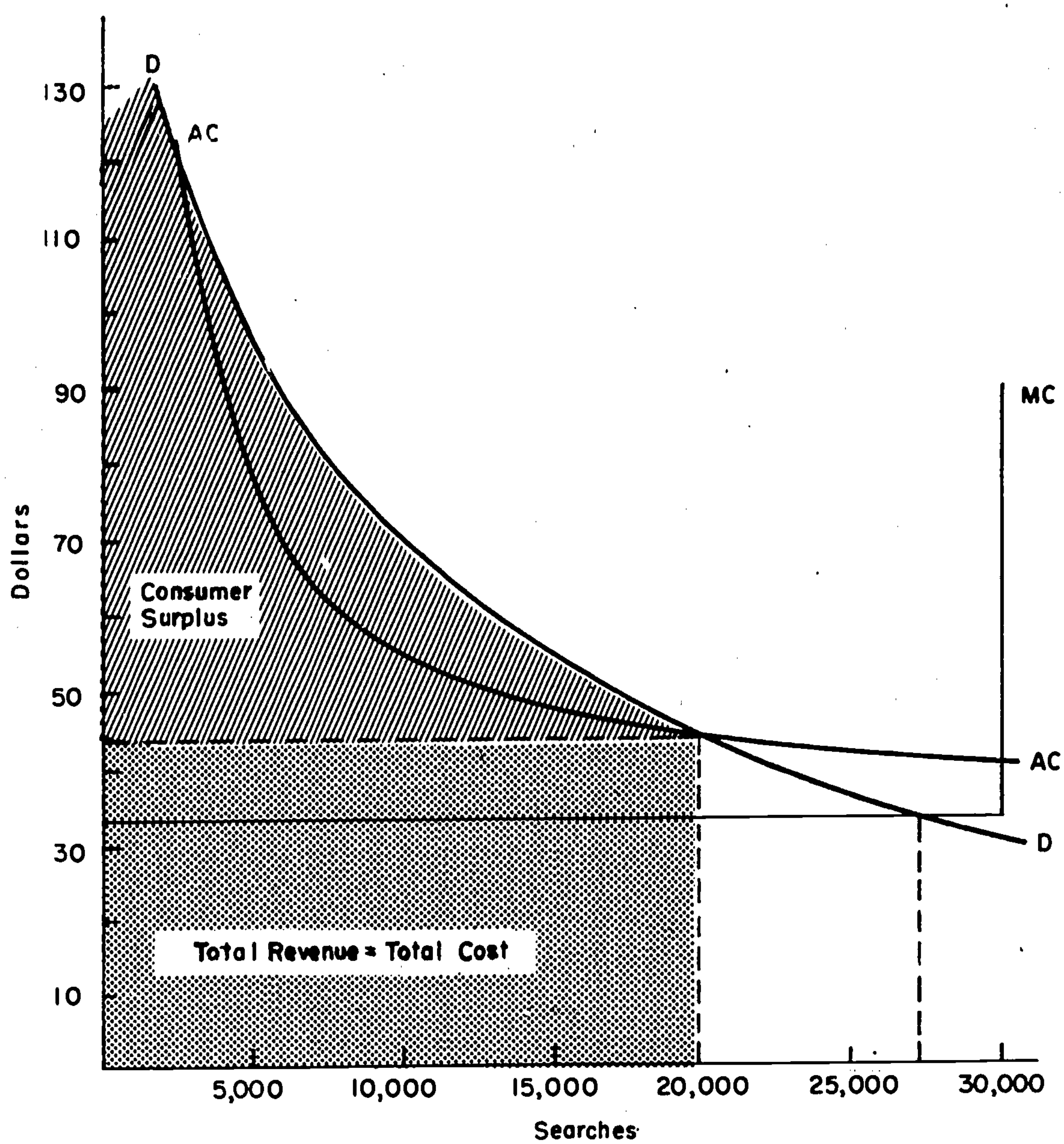

Figure 6 Average Cost, Marginal Cost and Demand: On-Site Entry, Fixed Capacity

Impact of Changing To Marginal
Cost Pricing From Average Cost
Pricing with Capacity Constraint

(Dollars in Thousands)	Value at P=AC (Q=20,000)	Value at P=MC (Q=28,000)	Change From P=AC To P=MC
Total Benefit	$1,633	$1,944	$311
Total Revenue	907	927	20
Consumer Surplus	726	1,017	219
Total Cost	726	1,173	266
Net Benefit	726	771	45
Producer Surplus (Profit)	-0-	-224	-224

Since there is no profit or loss (TC=TR), consumer surplus and net benefit are equal.

These results illustrate the cost recovery implication of average cost pricing. However, as was shown, net benefit is maximized when marginal cost pricing is used; i.e., P = MC = $33.13. The changes that occur when price is set equal to MC are shown in the column headed P=MC. Maximizing net benefit by using the P=MC rule increases output by 8,000 units and net benefit by $45,000. However, this increase in net benefit entails an operating loss ($224,355) equal to the fixed cost of the system (f + aN). This loss will occur for every level of output and elasticity when P=MC, F > 0 and MC constant.

This comparison of the outcome of the decision to set P=MC with that of setting P=AC is a specific example of the inconsistency of the goals of total cost recovery and maximization of net social benefit with declining average costs. The increase in total benefit ($311,000) is greater than the

increase in total cost ($266,000), so the choice of P=MC over P=AC can be viewed as a socially beneficial one. However, the move to P=MC, because of the resultant producer loss, implies a need for subsidization.

It should be noted parenthetically, that if the user market can be segmented (e.g., students vs. professionals or daytime users vs. night-time users), it may be possible charge different prices to each segment and thereby use "price discrimination" to recover costs. However, with declining average cost, price discrimination total cost recovery still implies charging some users more than marginal cost. Thus, the use of price discrimination in publicly funded systems raises many important questions of equity (e.g., who pays only marginal cost). A comprehensive treatment of the economics of price discrimination can be found in [12], especially Chapter 5, "Decreasing Costs and Price Discrimination."

VI. REMOTE ENTRY, FIXED CAPACITY

To extend the illustration of the application of cost-benefit analysis to the evaluation of more technologically advanced systems, a remote-entry version of the on-site entry system will now be considered. Batch processing rather than an interactive mode will still be assumed. While this does not represent the most advanced technology, it permits the use of the same queuing model and still serves to illustrate the major points.

A. System Cost

Typically, in a remote entry system, charges are made on the basis of the time required per search (connect time) rather than on a cost-per-search completed basis. Because the remote entry system is subject to congestion and increased waiting time as the utilization rate increases, user time and, therefore, user cost increases with utilization and is not constant over

the whole range of output. Because of this, each additional user contributes or adds to the average costs of all users, which means that the marginal cost of the added user will be greater than the average cost.

To illustrate these points, a new set of operating procedures and associated costs will be defined. Producer cost and user cost will be considered separately. Next, total cost will be examined, and the impacts of pricing alternatives on cost, cost recovery, maximization of social benefit and the level of system utilization will be examined.

1. Producer Cost

For the remote entry example it will be assumed that access to the system is provided through intermediaries, such as the regional medical libraries accessing the National Library of Medicine's MEDLINE system [19], and that requestors of searches are required to pick up the results of their searches. Further assumptions are: no screening is performed, the user/system interface is provided by the intermediary users, and the service time is the same as for the on-site entry case.

The effect of no screening is to eliminate both the fixed and the variable screening costs, C_4 and C_8. Requiring the user to pick-up results eliminates both the fixed and variable mailing costs, C_5 and C_9. Having the intermediaries provide the user/system interface shifts the interface cost, C_7, to the users. Thus, for the remote entry example, total producer costs become:

$$PC = f + aN = \$188,525 \qquad (14)$$

where $f = C_1 + C_2 + C_3$, and the factor a and the C_i are as defined for the on-site entry example.

2. User Cost

For the remote entry case, the cost to users is a combination of system charges, level of system utilization and other user incurred charges:

$$UC = (SC + LC) \times T_q + FC \qquad (15)$$

where UC = effective cost (price) to user

SC = System charge per unit of connect time

LC = user incurred labor costs per unit of connect time

T_q = average connect time per search

FC = user/system interface cost (C_7)

The average connect time per search, T_q, has four components: input, time, search time and output time as in the on-site case, plus waiting time. Waiting time, as illustrated in Figure 3, increases as the level of utilization, Q increases. The print-out of the search results is transmitted directly to the remote sites but done off-line. A print-out time of 10 minutes will be assumed and added to the connect time of each search for the example.

The system charge is assumed to include communications costs. Further, it is assumed that the labor cost rate and interface costs are the same among all users and constant. The labor cost rate (LC) is assumed to be \$.12 per minute for each minute of connect time.

The assumption of a constant labor cost is equivalent to assuming a constant cost of time for users and is reasonable for the case where an intermediary does the actual inputting. However, the shape of the cost of time curve can play an important role in a system cost-benefit evaluation [8, p. 889-891]. Only when all users have the same cost rate and the rate is constant does minimizing average waiting time also serve to minimize total user cost.

3. Total Cost

Total system costs are the sum of the producer cost and the user cost. With the groundrules and assumptions described above, all producer costs are now fixed (i.e., PMC=0). All user costs are variable and an increasing function of utilization for any chosen system charge, SC. The curves for SC=$50 are shown in Figure 7. The shapes of these curves do not depend on the assumption that producer marginal cost equal zero, but only on the assumption that the producer marginal cost be constant.

As can be seen in Figure 7, average producer cost (PAC) declines over the whole range as in the on-site entry case. However, because the user marginal costs (UMC) are no longer constant, the average total cost (ATC) curve is U-shaped with UMC > ATC at all points to the right of the intersection of the curves. This intersection occurs at about Q=32,850 and AC=MC=$34.85 for SC=$50. Raising the SC will move the UMC curve and the point of intersection upward and to the left. Thus, it is possible to manipulate the curves to achieve a desired user marginal or average (AUC) cost at the capacity level of output.

Since the user cost per search is dependent on the level of utilization as well as on the system charge, it is not possible to use SC alone to implement marginal cost pricing. Regardless of where SC is set, if price is uniform, each user will pay the average cost. To achieve marginal cost pricing under these conditions requires the imposition of some form of congestion toll. The cost-benefit implication of this is examined in the following paragraphs.

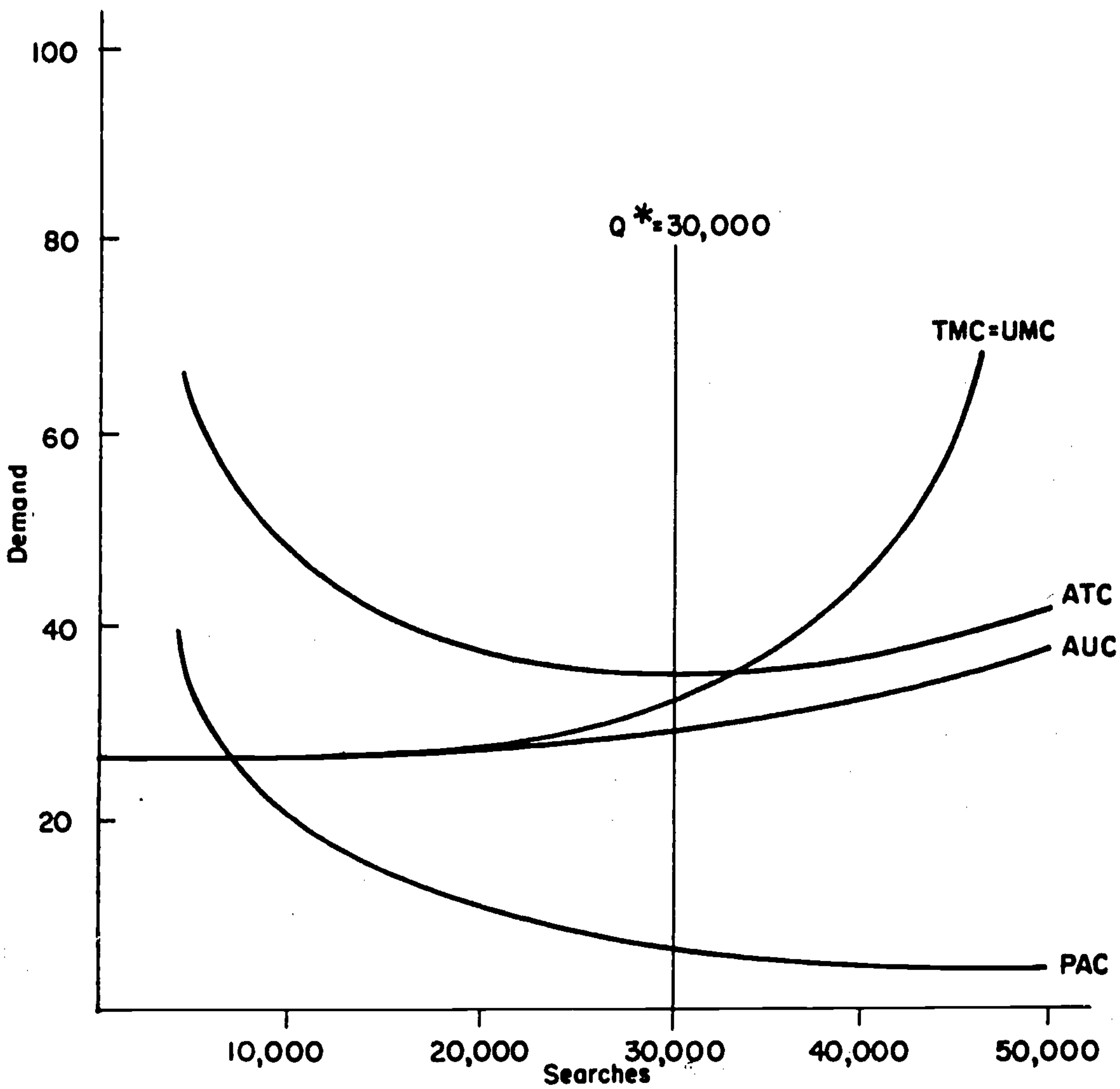

Figure 7. Average, Marginal and Total Costs:
Remote Entry, Fixed Capacity

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B. Pricing Alternatives

To illustrate the implications of pricing alternatives for the remote entry example, assume that the convenience of the remote access system generates a greater demand. Let there be an upward shift in the demand curve such that the demand curve shifts from the level shown in the on-site example with Q=28,000 when P=$33.13 to Q=28,000 when P=$40.00. This new level of demand is shown by the demand curve D in Figure 8.

This new demand curve intersects the capacity constraint of Q*=30,000 at P=$37.70. By setting SC at $88.00, the average user cost curve (UAC) intersects the demand curve at this same point, labeled A, in Figure 8. Thus, if SC is set at $88.00 and average cost pricing is used, full utilization of capacity will occur and total benefit will be maximized, given the demand curve, D.

However, it is evident from the cost curves in Figure 8 that with a system subject to congestion each additional user will contribute a (marginal) cost to all users that is greater than the price paid by that user. Thus, the additional users are imposing a higher cost on the system than they are paying. In effect, there are cost externalities not reflected in the (average) price.

Interestingly, under these circumstances, pricing policies designed to insure that the unit price to users equals marginal cost will not necessarily lead to the maximizing of net benefit. The enforcement of a policy to make users pay marginal cost could be accomplished in the example shown in Figure 8 by adding a "congestion toll" equal to the vertical difference between UMC and UAC at point B. This would raise the price to the user to the point where D=MC=$41.60 and reduce the level of demand to Q=26,000.

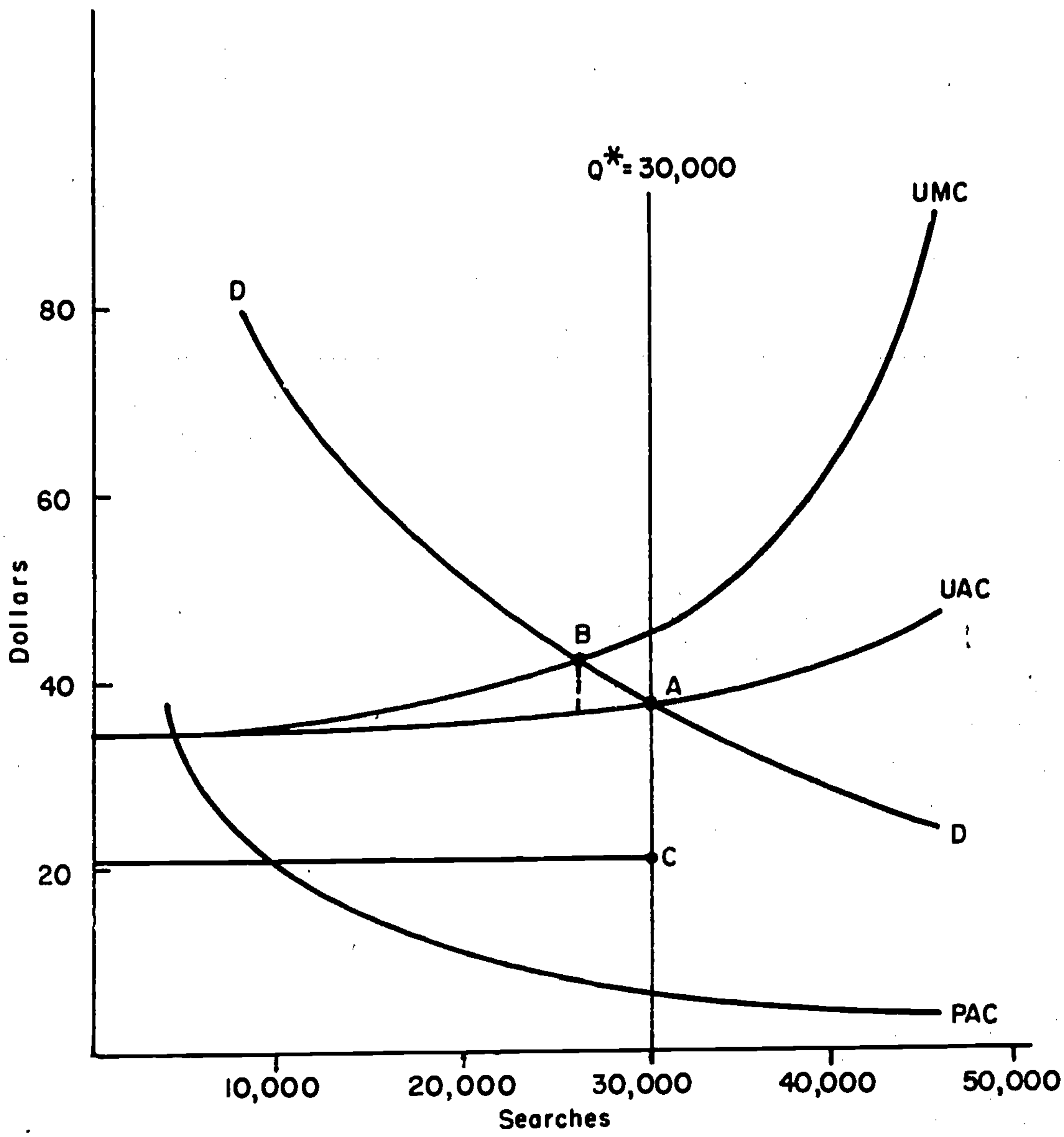

Figure 8. Remote Entry Demand and Cost: Fixed Capacity

Does such a quasi-marginal-cost pricing alternative result in a net benefit greater than would result with average cost pricing? It may. However, it may also only result in a reduction of utilization and a higher unit price to the remaining users. This is illustrated below with figures for the example.

Impact of changing to Marginal
Cost pricing from Average Cost
Pricing with Capacity Constraint

(Dollars in Thousands)	P=AUC Q=30,000	P=UMC Q=26,000
Total Benefit	2094	1934
Total Revenue	629	649
Consumer Surplus	1465	1285
Total Cost	1131	1082
User Incurred	(502)	(433)
System Charges	(629)	(649)
Net Benefit	963	852
Producer Surplus	440	460
(Dollars)		
System Charge per Hour	88.00	88.00
Congestion toll	-	4.75
Price to User per Search	37.70	41.60
Producer Cost per Search	6.30	7.25
Producer Charge per Search	20.97[a]	24.98[b]
User Incurred Cost per Search	16.73	16.92

a) \$88/hr. x 14.3 min./search ÷ 60 min.
b) \$88/hr. x 13.8 min./search ÷ 60 min. + \$4.75/search

The figures show that for this example, the imposition of a congestion toll to raise user price to UMC from UAC decreases net benefit rather than increasing it. These results illustrate two important and related points: 1) the congestion encountered with incrcased utilization of a fixed capacity remote entry system can create cost externalities, and 2) the impact of these externalities on net benefit should be carefully reviewed in each case since a preferred outcome is not always achieved by making users pay marginal cost, but depends on the position and slope of the cost and demand curves.

C. Cost Recovery

For the example chosen, cost recovery was not an issue. Even though there was a declining producer's average cost (PAC) curve, it was below the UAC curve over the relevant range. This is largely a reflection of the fact that producer marginal cost (PMC) was assumed to be zero while the UMC was assumed to be positive. If instead, PMC was positive, but also constant, the PAC curve would shift upward while still retaining its negative slope.

The line intersecting the capacity constraint at point C in Figure 8 shows the producer charge per search (average revenue) resulting from an SC of $88.00. In the event that the PMC was great enough to cause the PAC curve to shift up above this line, the question of cost recovery vs. net benefit maximation would again occur. The same basic procedures that were applied to the on-site entry example could be applied. The only major difference being that the major pricing alternatives would be PAC vs. UAC rather than PAC vs. PMC.

VII. CAPACITY INVESTMENT AND PRICING

In this section, the assumption of fixed capacity is relaxed, and questions of pricing alternatives with possible changes in capacity are examined. Capacity is not fully divisible, in the sense that additional search capacity can be added in small increments. The relationship between cost and capacity and assumptions as to the size-increment options available are presented first. Next an illustration of the cost and benefit implications of pricing and capacity investment alternatives are examined for the on-site entry case, using the same hypothetical system cost that was described for the fixed capacity case, modified by the amount needed to increase capacity. Finally, these same questions are examined for the case of remote entry, using the modified remote entry system costs.

A. System Cost and Capacity

The question of economies of scale in computing power has been given a substantial amount of attention. As early as the 1940's H. R. Grosch asserted that for average cost per unit of effectiveness for computer equipment decreases substantially as the size of the computer increases. This is a concept that has become known as Grosch's Law [24, p. 315]. More specifically, Grosch's Law can be expressed as:

$$C/E = K/E^{\frac{1}{2}} \qquad (16)$$

where C = cost

E = effectiveness (performance or speed)

K = constant

A significant amount of empirical work has been done to examine the validity of Grosch's assertion [15, 16, 24, 25]. Although the results are somewhat mixed, they generally appear to support equation 16 and indicate the existence of economies of scale in computer power.

For purposes of illustration and further discussion, it will be assumed that economies exist and that they follow the pattern indicated in equation 16. However, it is important to distinguish between computing power and computer services. Computer services can encompass a wide range of activities, and as Selwyn [23] has demonstrated, the evidence on the existence of economics of scale is mixed when several types of service, each with a different production function, are offered.

Multiplying both sides of equation 16 by E gives

$$C = KE^{\frac{1}{2}} \qquad (17)$$

The values for both equation 16 and equation 17 are plotted in Figure 9 as functions of both service time and effectiveness. These were curves derived by arbitrarily setting the effectiveness of the existing system with a service time of 2.1166 minutes equal to one and then calculating the effectiveness impact of decreased service time relative to that reference point.

In practice, the possible changes to system capacity are not continuous and large indivisibilities exist. For the example, it will be assumed that the minimum capacity increments possible, as measured in increased effectiveness or decreased service time, are fractional multiples of current effectiveness and equal .50. Using the same criterion that $W(10) \geq .95$, new capacity value can then be calculated for each of the service times. These are shown in Figure 9 by the vertical lines and the corresponding Q*.

One final point is that the cost of a change in systems capacity as contrasted to the cost of a system will entail one time conversion costs. These costs can be significant but, for the example, they will not be included. A summary of service times, computer related costs (C_3) and capacity is shown below:

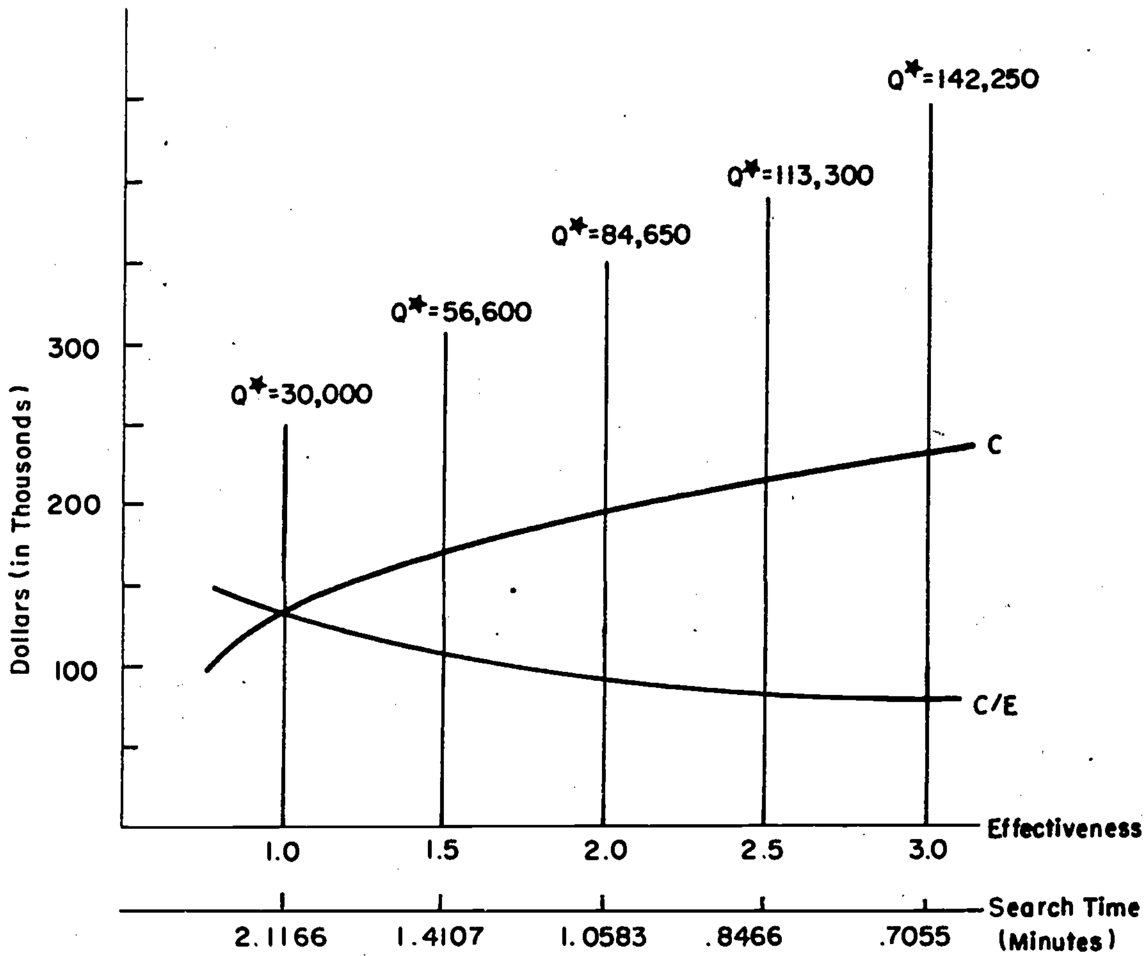

Figure 9. Computer Cost and Capacity as a Function of Service Time
W(10) = .95

Service Time	Computer Related Cost (C_3)	Capacity: Maximum Searches for W(10) > .95
2.1166	135,000	30,000
1.4107	165,400	56,600
1.0583	190,900	84,650
.8466	213,500	113,300
.7055	233,800	142,250

B. On-Site Entry

Using the capacity cost assumptions from the preceding section, it is possible to calculate new cost curves for the on-site example. These are shown in Figure 10. The average cost curve AC1 and the marginal cost curve MC1 are identical to those in Figure 6. The curves AC2 and MC2 are the corresponding curves for the capacity investment which increases effectiveness 50%, reducing service time to 1.4107 minutes and increasing capacity to 56,600 searches per year.

Assume again a one time shift in demand from the level shown in Figure 6, this time to the level shown by the curve D in Figure 10. This D curve intersects the MC1 in the vertical section at Q=30,000 and P=$50.00. The curve also intersects the AC2 curve at Q=37,900 and P=$39.90 and the MC2 curve at Q=45,740 and P=$33.13.

The alternatives open to the producer are to ration existing capacity by charging $50.00 per search (alternative 1); to expand capacity and price at average cost of $39.90 (alternative 2); or to expand capacity and set P=MC2 (alternative 3). The outcomes for each of these decisions are tabulated below:

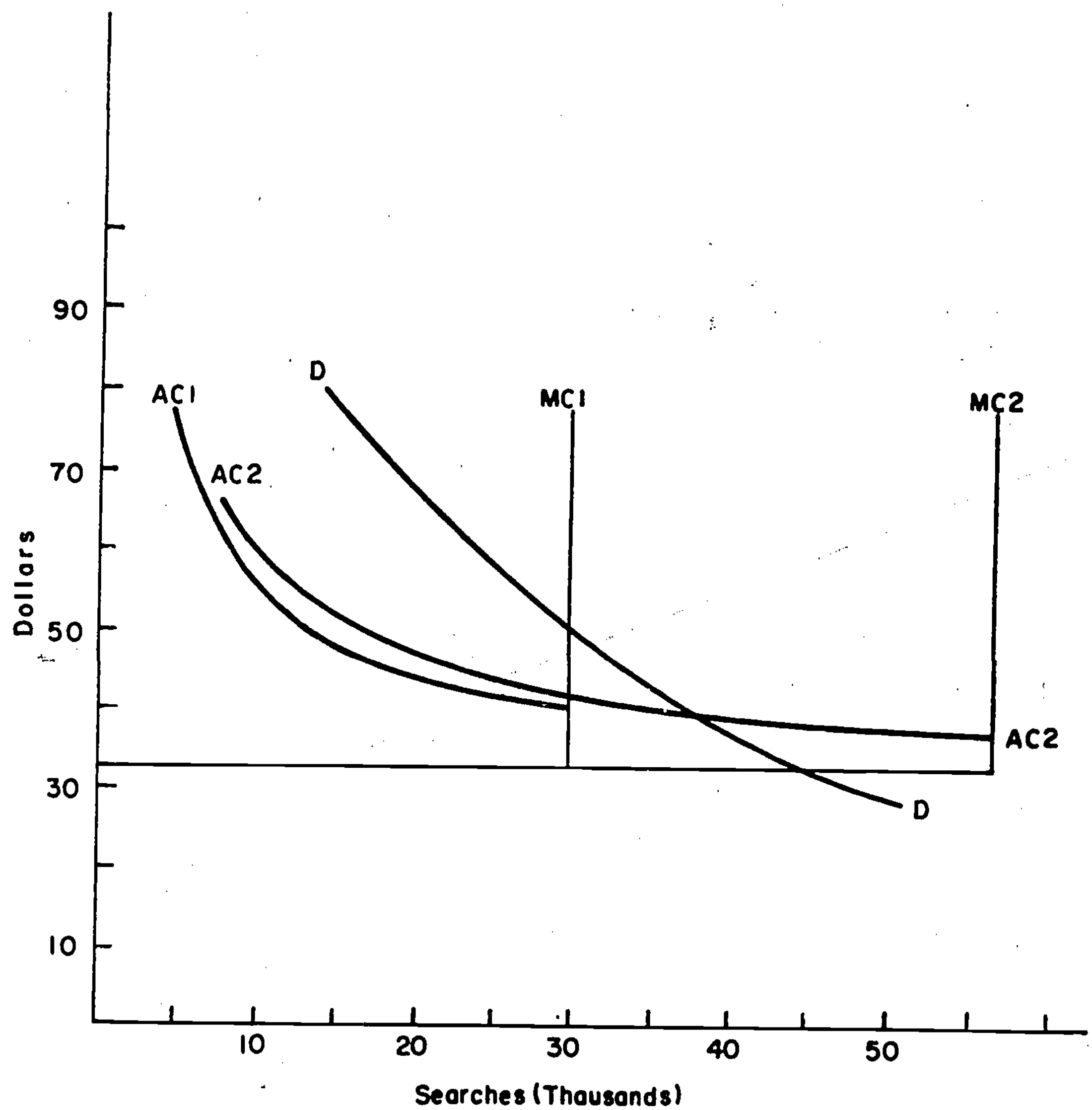

Figure 10. Pricing and Capacity Alternatives:
On-Site Entry

Impact of Alternative
Pricing and Capacity Decisions

	Alt. 1	Alt. 2	Alt. 3
	values at Q=30,000 and P=MC1	values at Q=37,900 and P=AC2	values at Q=45,740 and P=MC2
Total Benefit	2700	3056	3345
Total Revenue	1500	1512	1515
Consumer Surplus	1200	1544	1830
Total Cost	1249	1512	1789
Net Benefit	1451	1544	1556
Producer Surplus	251	--	- 274

These figures show that the first alternative involves a significant producer surplus. Moving to the second alternative results in an increase in net benefit but entails the elimination of the producer surplus. The third alternative further increases net benefit but again entails a producer loss equal to the fixed cost of production. As with the fixed capacity case, the alternative which maximizes net benefit (alternative 3) significantly increases output and lowers price but entails a loss to the extent of fixed cost. Thus, the example illustrates that for systems with constant marginal cost, with or without fixed capacity, strategies which increase utilization can lead to higher net benefit while implying producer loss.

C. Remote Entry

Since capacity investment for the remote entry system reduces service time, it also reduces waiting time and, therefore, cost to users for any given level of utilization. Thus, such a producer investment has a direct impact on user costs in addition to its effect on total net benefit. The impacts of pricing alternatives with a change in capacity will be illustrated using the same demand curve that was used for the remote entry, fixed capacity example. This curve is shown in Figure 11 as the curve labeled D.

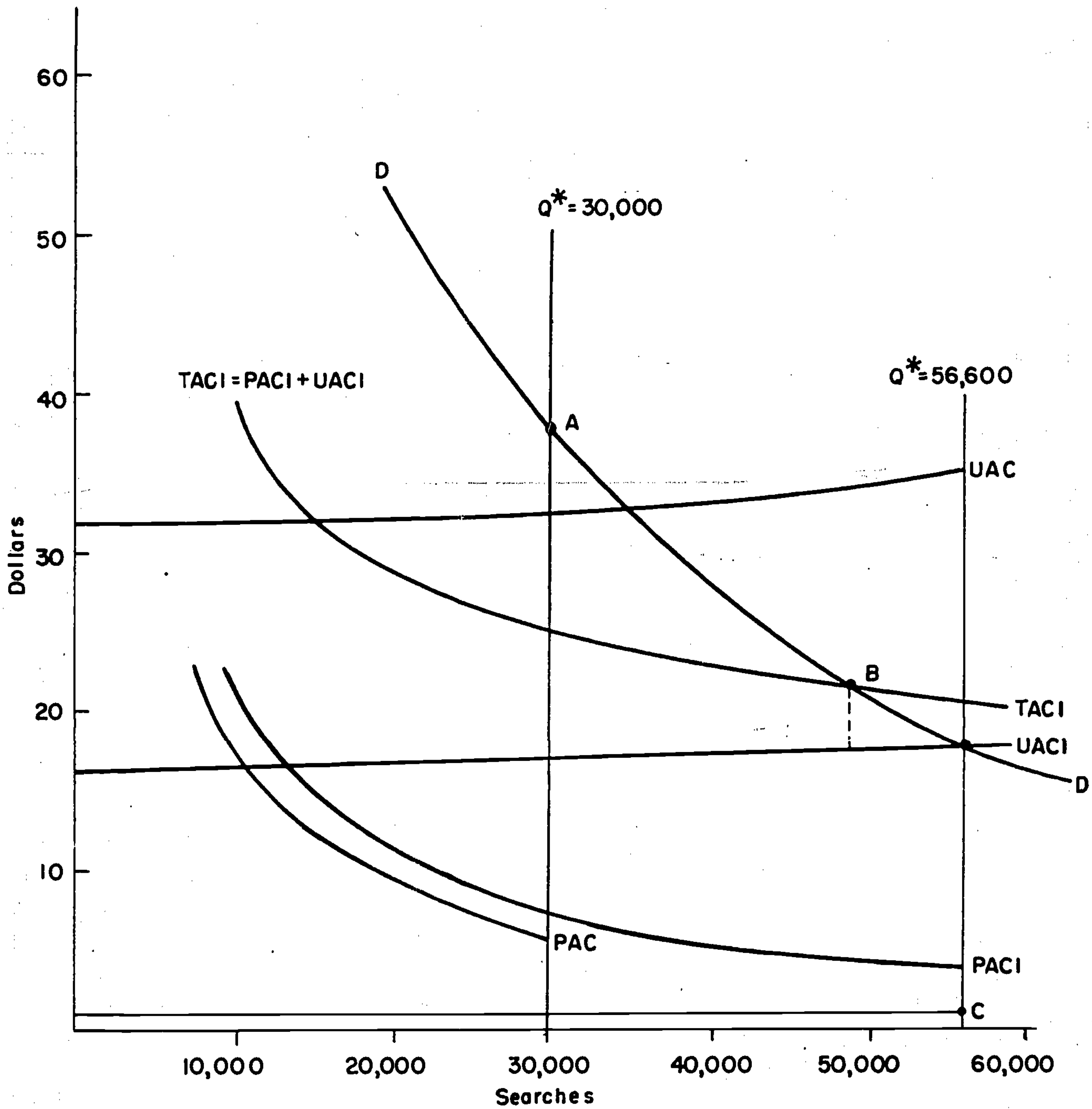

Figure 11. Pricing and Capacity Alternatives: Remote Entry

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The point A in Figure 11 is the point where UAC=D for the old service time of two minutes and a system charge of $88.00. The curve PAC is the producer's average cost curve for that same service time. The curve UAC is the user average cost curve resulting from reducing service time to 1.4107 minutes (increasing capacity to 56,600) with the same service charge of $88.00. As can be seen this curve now intersects the demand curve at about Q=35,000 and P=$32.00, illustrating how capacity investments shift the UAC curves downward and to the right.

Using the point A and Q*=30,000 as a point of departure, the major alternatives which will be compared are: continue with the existing practice (i.e., point A), increase capacity and set price to maximize net benefit, and increase capacity and set price to recover cost. The results of the first alternative were calculated for the fixed capacity example, and are summarized again in the first column headed "Point A" in Table 1.

To achieve the second alternative, it is first necessary to increase the capacity cost. Again a capacity investment which increases effectiveness by 50 per cent and capacity to 56,600 searches by reducing service time to 1.4107 minutes will be used for the example. This shifts producer's average cost up. This is illustrated in Figure 11 by the curves PAC which corresponds to Q*=30,000 and PAC1 which corresponds to Q*=56,600.

With the appropriate reduction in SC, it is possible to again maximize total benefit by having P=UAC1=D at Q*=56,600. For the example this occurs when SC=$3.55. The resulting UAC1 at Q*=56,600 is $17.50. A summary of the impacts of increasing capacity and pricing to maximize total benefit is shown in the second column headed P=UAC1 in Table 1.

TABLE 1

IMPACT OF ALTERNATIVE PRICING DECISIONS WITH EXPANDED CAPACITY FOR THE REMOTE ENTRY EXAMPLE

(Dollars in Thousands)	POINT A Q=30,000	P=UAC1 Q=56,600	P=TAC1 Q=49,500
Total Benefit	2094	2800	2661
Total Revenue	629	48	219
Consumer Surplus	1465	2752	2442
Total Cost	1131	1209	1042
User Incurred	(502)	(738)	(823)
System Charges	(629)	(471)	(219)
Net Benefit	963	1591	1619
Producer Surplus	440	-171	-0-
(Dollars)			
System Charges per Hour	88.00	3.55	3.55
Surcharge	-	-	3.64
Price to User per Search	37.70	17.50	20.90
Producer Cost per Search	6.30	3.85	4.42
Producer Charge per Search	20.97[a]	.85[b]	.78[c]
User Incurred Cost per Search	16.73	16.65	16.47

a) \$88.00/hr. x 14.3 min./search ÷ 60 min.

b) \$3.55/hr. x 13.9 min./search ÷ 60 min.

c) \$3.55/hr. x 13.2 min./search ÷ 60 min.

The increase in the net benefit between this alternative and the "Point A" alternative is quite significant. However, in this example, unlike the fixed capacity case, maximizing total benefit implies a producer loss. The average producer income per search resulting from setting SC=\$3.55 is \$.85 at Q*=56,600. This is shown by the horizontal line which intersects the capacity constraint at the point labeled C. The average producer cost at this point is \$3.85 as shown by the intersection of the curve PAC1 and the capacity constraint.

A cost recovery strategy for this example would be to add a surcharge to UAC1 sufficient to cover the producer cost. This will occur when P=TAC1=D, where TAC1=UAC1+PAC1. To illustrate this the total cost curve TAC1 is also shown in Figure 11. This TAC1 curve intersects the demand curve at point B for Q=49,500. At this Q, PAC1 is \$3.64, which is the vertical distance from point B to the UAC1 curve at Q=49,500. Thus, adding a surcharge of \$3.64 per search would result in a demand level of Q=49,500 at a user price per search of \$20.90. The results of this alternative are shown in column three of Table 1 headed P=TAC1. As expected, the cost recovery strategy again produces a slight increase in net benefit compared to P=UAC1 decision.

However, the most significant point is that as capacity increases relative to demand, the influence of waiting time is reduced and average and marginal cost become almost constant. (In the example, ρ=.85 at Q=50,000 for Q*=30,000, as compared to ρ=.57 at Q=50,000 for Q*=56,600.) As a result, for high relative capacity, the remote entry system cost curves become increasingly like the on-site system cost curves with declining average (producer) cost and constant marginal (producer and user) cost.

VIII. POLICY IMPLICATIONS

The examples presented illustrate the various ways in which declining average cost occurs in the operation of automated scientific information retrieval systems, and indicate the way in which conflicts can arise between cost recovery and the maximization of net social benefit. Declining average costs, and "public good" properties can be taken as justification for public subsidy. Having demonstrated the existence of declining average costs for at least some instances for automated scientific information retrieval systems, the questions then become: what are public goods, and can automated scientific information retrieval systems be viewed as public goods?

A. Public Goods

The features of a public good or service which distinguish it from other goods and services produced in the economy have been examined extentively [7, 9, 20, 27] and can be characterized as follows:

> "There are certain goods that have the peculiarity that once they are available no one can be precluded from enjoying them whether he contributed to their provision or not. These are the public goods. Law and order is an example, and there are many others too familiar to make further exemplification worthwhile. Their essential characteristic is that they are enjoyed but not consumed (and that their benefits are derived) without any act of appropriation" [7, p. 4].

Two important features of public goods are: since no one can be precluded from enjoying their benefits, the price mechanism is ineffective as a means for allocating the enjoyment of their benefits; and since they are "enjoyed but not consumed" the costs of providing these goods is largely unaffected by the number of persons benefiting from them. Because of these implications, public goods are generally provided by government or by publicly financed organizations.

B. Semi-Public Goods

Some goods or services, though not pure public goods have some attributes of public goods combined with some attributes of private goods. Returning to the notation of equation 10, a formal definition of such a "semi-public" good is the following: Let

$$TC = F + bQ$$

where F is the fixed component, b is the cost per unit of output per unit of time, and Q is the number of units of output per unit of time. Then,

> "If we 'all enjoy in common' a collective good, the case where $b=0$ characterizes a pure collective good, since no additional cost is necessary for an additional consumer to enjoy it. If $F=0$ we are at the other extreme where there is no element of communality. We occupy the in-between situation of semi-public good if $F > 0$, constituting the common component of the good, and $b > o$, constituting its private component." [1, p. 666]

Thus if the good or service is in some sense a "collective good" (i.e., a public good), subsidization, at least up to the value of F should be given consideration if declining average costs are also present.

C. Automated Information Systems

Using a logic similar to that set forth for journal publications [1, p. 665-666], it would appear that automated information retrieval systems do indeed have public good as well as private good attributes and can be viewed as semi-public goods. The publications indexed and abstracted in the data base and representing the ideas contained in the publications are the core of the public good component of automated information retrieval systems. This information is not consumed when it is used, and in that sense availability to some does not reduce availability to others. In addition, the cost of the original research, editing and printing may be borne by scholars, universities, foundations and other parts of the public sector.

However, the benefits of automated information systems cannot be simply enjoyed without special provision for access to the ideas contained. This access is consumed and affects the availability of the information retrieval service to others when it is consumed. Thus, automated information retrieval systems have a private good aspects as well as a public good aspect and, in this sense, are a semi-public good.

The conclusion that automated scientific information retrieval systems do have public goods attributes and, in <u>some</u> cases, declining average costs leads to the following major conclusion regarding the subsidization of these systems. If it can be demonstrated that declining average costs persist for all reasonable pricing and capacity alternatives, a given information retrieval system should be subsidized up to the difference between producer average total cost and producer marginal cost. A corollary conclusion is that the subsidization of each system should be periodically reviewed to determine if the initiating conditions for subsidization continue to exist.

APPENDIX A

MAXIMIZATION OF NET SOCIAL BENEFIT

Net benefit, NB, can be expressed as:

$$NB = TB - TC, \qquad \text{(A-1)}$$

where,

TB = Total Benefit = TR + CS

TC = Total Cost

TR = Total Revenue

CS = Consumer Surplus

Differentiating Equation A-1 with respect to output and setting the result equal to zero, it is possible to solve for the net-benefit-maximizing or optimal price:

$$\frac{d(NB)}{dQ} = \frac{d}{dQ}(TR + CS) - \frac{d(TC)}{dQ} = 0. \qquad \text{(A-2)}$$

Since $(TR + CS) = \int_0^q P(Q)dQ$, where $P(Q)$ is the demand curve [28, p. 812], the term $\frac{d}{dQ}$ (TR + CS) = price, P.

By definition, marginal cost, MC, is the cost of producing the last unit of output so that $MC \equiv \frac{d}{dQ}(TC)$. Thus, Equation A-2 shows that total net benefit is maximized when P = MC. The demand curve is also the average revenue curve since TR = Q × P; therefore, P = MC = AR when net social benefit is maximized, and P is the point of intersection of MC and the demand curve (see point B in Figure 2).

With a fixed capacity, the problem of optimal pricing becomes one of constrained maximization; i.e.,

$$\text{max. } NB = (TR + CS) - TC$$
$$\text{for } Q < Q^* , \qquad \text{(A-3)}$$

where Q^* is the maximum attainable output level. The solution of this problem requires the use of a Lagrangian multiplier, denoted as λ [28, p. 812]. Using a Lagrangian, equation A-3 becomes:

$$\max.\ L(q,\lambda) = (TR + CS) - TC - \lambda(Q-Q^*). \qquad \text{(A-4)}$$

Differentiating partially with respect to Q and λ, and equating the results to zero gives the benefit maximizing solution:

$$P = MC + \lambda. \qquad \text{(A-5)}$$

If the constraint is not operative (i.e., $Q < Q^*$), then $\lambda = 0$ and the optimal price is $P = MC$ [28, p. 813].

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This paper examines the cost-benefit implications of alternative pricing and capacity investment decisions for automated scientific and technical information retrieval systems. Two typical systems are examined and numerical examples presented. In the first system, search requests are entered on-site. The numerical examples show how setting price to maximize net social benefit precludes total cost recovery and implies subsidization. In the second hypothetical system, search requests are entered from remote access terminals. Allowance is made for random arrival rates, and distinction is made between system charges to users and other user incurred costs. With these refinements, the numerical examples show how, for certain ranges of output, total cost recovery is consistent with the maximization of net social benefit. The paper then examines the "public good" attributes of scientific and technical information retrieval systems and concludes that such systems can be viewed as "semi-public goods," since the information stored has the characteristics of a public good while access to this information has the characteristic of a private good. Based on the public good considerations and the numerical examples, the paper concludes that subsidization for the fixed costs is warranted to the extent that all reasonable alternatives which maximize net social benefit preclude total cost recovery.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Automated information retrieval; cost benefit; public good; scientific and technical information; semi-public good; subsidization; total cost recovery; user charges

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